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Alternatives: Beyond SUSY Searches in CMS

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Abstract

The CMS discovery potential for extra dimensions in the ADD and Randall-Sundrum scenarios, for new heavy gauge bosons Z' and for contact interactions in dilepton, diphoton and dijet final states is reviewed. Special attention is paid to systematic effects both on the experimental and theory sides. The evolution of the discovery strategies and reach from LHC start-up to high accumulated luminosities are presented.

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1 Introduction

With the approaching turn-on of the LHC accelerator near Geneva the CMS collaboration is preparing to search for new physics on a wide front. Here we concentrate on searches using “simple” final states with no missing energy where we can reconstruct the invariant mass of the decaying system: dielectrons, diphotons, dimuons and dijets. These channels can provide an early discovery: “easy” in the case of resonances manifested as a mass peak, or “not-so-easy” in the more subtle non-resonant (or just a resonant tail) case. The LHC is a di-{lepton, photon, jet} factory (see e.g. Figure 1), where we can test the Standard Model and many new physics scenarios like compositeness, Z' gauge bosons and extra dimensions up to the highest momentum transfers opening at the LHC, and eventually fix the scale for new physics.

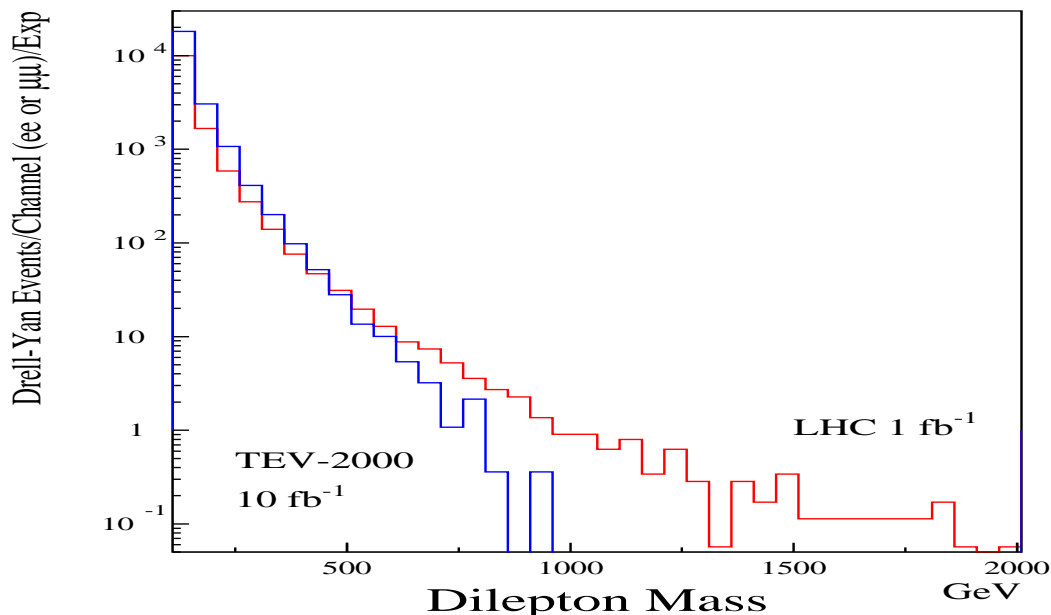


Figure 1: The first 1 fb^{-1} of LHC data will start probing the TeV scale in the dilepton channels (PYTHIA simulation for rapidities up to $|2.5|$).

2 Results

The CMS collaboration has just completed a detailed Physics Technical Design Report [1]. All results for the channels under discussion are taken from there. They are based on full detector simulation and reconstruction and detailed studies of the backgrounds and systematic uncertainties.

The dielectron (diphoton) reconstruction takes into account the effects of preshowering, tails in the hadronic calorimeter and energy corrections. One of the most important effects is the saturation correction: above 1.7 TeV in the barrel and 3 TeV in the endcaps, see Figure 2a. The mass resolution in the barrel is 0.6% (7%) without (with) saturation.

The dimuon efficiency (trigger and reconstruction) varies between 97 and 93% for masses between 0.1 and 5 TeV. The main systematic effect affecting the mass resolution is the misalignment of the muon chambers. At start-up the resolution at 1 TeV is expected to be $\sim 10\%$, with the accumulation of data it will improve to 4–5%. The effects on the dimuon cross section are summarized in Figure 2b. The dijet uncertainties on the cross section as a function of mass from energy scale, resolution and PDF uncertainty [2] are given in Figure 2c.

In the absence of a pronounced mass peak the searches are more difficult. We have developed ratio methods by using the ratios of real data from different phase space regions (enriched or depleted of contributions from possible new physics). Many things cancel in the ratios: luminosity, absolute efficiency, K-factors etc. Absolute values are not important, only the *shapes* as function of mass. Moreover, the dependence on simulations using the Monte Carlo method is reduced when using data ratios. One example is the use of double ratios [3]: ratio of data at high dimuon masses to data at a normalization scale of e.g. 250–500 GeV and the same ratio for simulated events for compositeness searches (Figure 2d). If theory understanding and detector modeling are both perfect the double ratio is always one if the Standard Model is

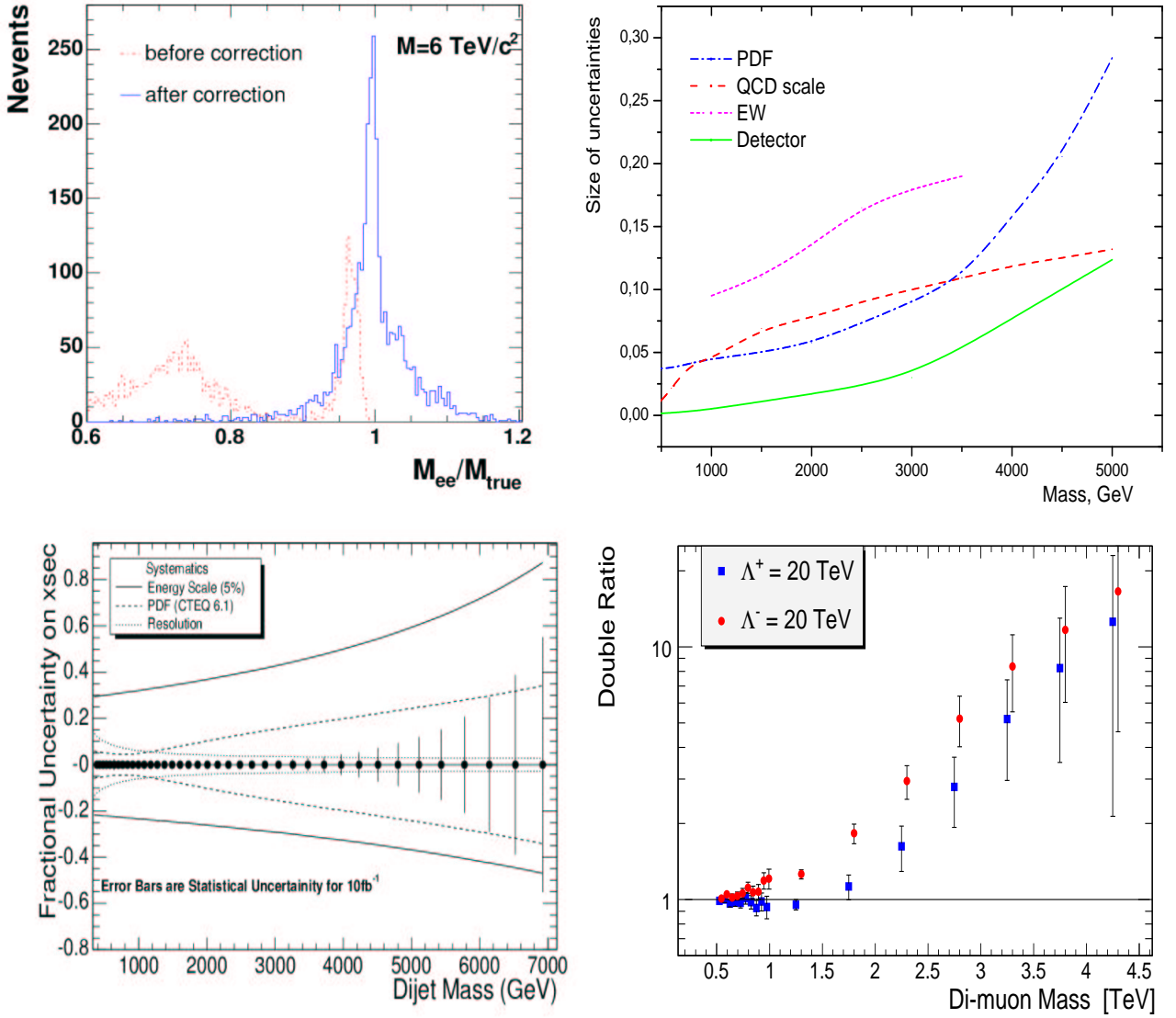
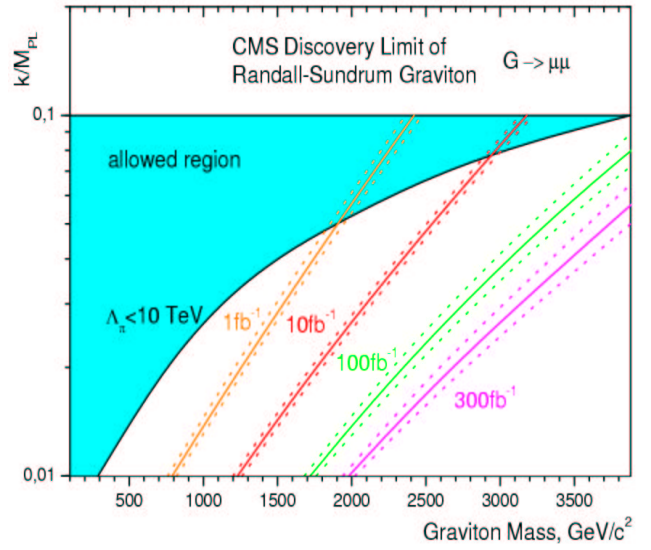
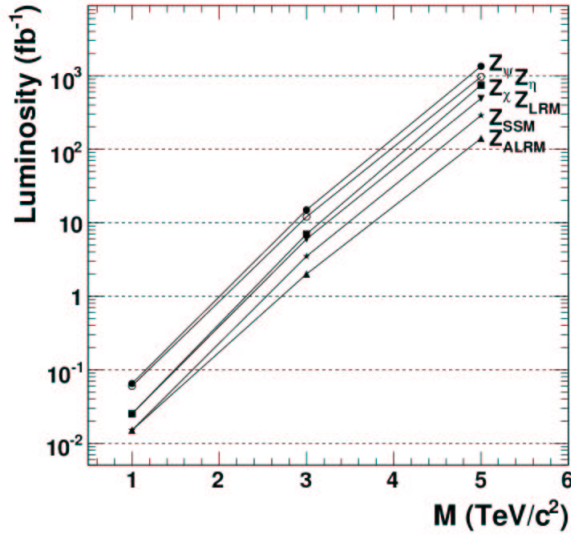


Figure 2: Top left (2a): dielectron mass reconstruction with and without saturation correction. Top right (2b): systematic effects (detector and theory) on dimuon cross section measurements. Bottom left (2c): systematic effects (detector and theory) on dijet cross section measurements. Bottom right (2d): the double ratio method for compositeness search with dimuons.

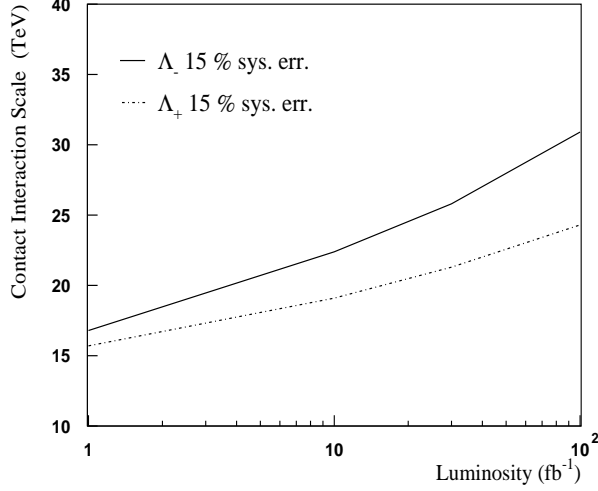
valid. Another example is the ratio of central and more forward dijet events [4], reminiscent of the classical Rutherford experiment.

Now we turn to the 5σ discovery reach for different channels. The Z' hunt for 6 different models is illustrated in Figure 3a. As can be seen already with samples of $10\text{--}100 \text{ pb}^{-1}$ we can probe the 1 TeV scale, expanding to 3 TeV for 10 fb^{-1} and ultimately to 4–5 TeV for different models. Moreover, using the angular distribution from the Z' decays we can obtain spin information to distinguish between Z' models or different scenarios like gravitons (for new developments in this area see e.g. [5]). The discovery reach for the Randall-Sundrum scenario of extra dimensions as function of mass and coupling is shown in Figure 3b. The ADD scenario with different number of extra dimensions is studied as well. The compositeness search using double ratios is illustrated in Figures 3c-d. As can be seen from the difference between the cases with generous 30% and ambitious 3% systematic uncertainties, up to 10 (100) fb^{-1} for negative (positive) interference we are dominated by statistical uncertainties. Scales of tens of TeV can be probed.

The CMS detector can measure cross sections and forward-backward asymmetries for di-{electron, photon, muon, jet}



Contact Interactions LL 5 σ Discovery in CMS at LHC



Contact Interactions LL 95 % CL Exclusion in CMS at LHC

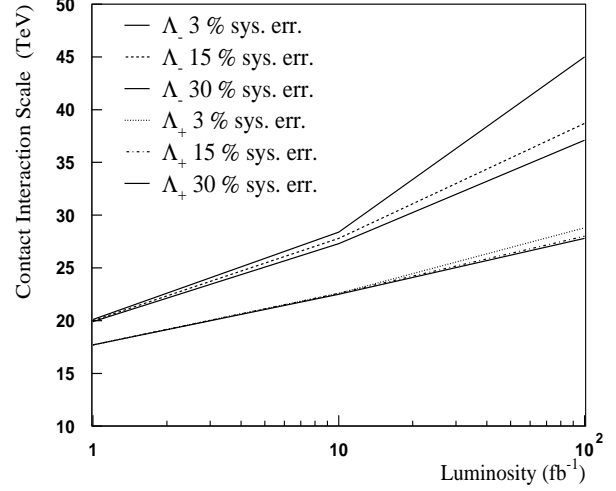


Figure 3: Top left (3a): discovery reach for different Z' models with dielectrons (comparable limits with dimuons). Top right (3b): discovery reach for Randall-Sundrum gravitons with dimuons (comparable limits with dielectrons). Bottom left (3c) and Bottom right (3d): discovery reach and 95% CL exclusion limits for LL compositeness models with dimuons. The evolution from LHC start-up to high collected luminosities is given in all cases.

final states up to the highest masses accessible at the LHC. This provides a rich search field for early discoveries at the multi-TeV scale, starting with resonances. We have developed ratio methods for non-resonant searches, resulting in reduced systematic uncertainties, mainly dependent on shapes as function of invariant mass instead of absolute values. The next couple of years will be very challenging as we ready the detector, data acquisition and software for first data, and exciting as we work and dream of fixing and exploring new physics scales.

References

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